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AN ELECTRIC CIRCUIT MODULE FOR SUPPLYING CONTROLLED  
FREQUENCY ELECTRIC POWER TO A LOAD.

The present invention relates in general to an electrical circuitry and more particularly to a circuit module for supplying electric power of a desirably controlled frequency to a load such as an electric motor, which is applicable, for example, to a frequency conversion circuit.

Generally, a prior art frequency conversion circuit is known as disclosed in Japanese Patent Publication No. 62-42472, published September 8, 1987. The circuit described in the aforementioned publication has circuit switching elements for changing the direction in which a pulsating current is carried constituted all of thyristor elements, and a desired frequency is obtained from controlling an ignition timing of the thyristors.

Such prior art comprises a single thyristor module containing a plurality of thyristors for directly controlling power principally, a single diode module containing a plurality of diodes for rectification, a drive circuit for the thyristors, and an ignition timing control circuit of the thyristors.

Since an ON/OFF characteristic of the thyristor is utilized, the prior art has a characteristic that the circuit automatically becomes off at the zero cross time of a pulsating current to be impressed. Accordingly, the direction of an electrical current to the load is changed generally at the zero cross point, a frequency of the

alternating current generated from the frequency conversion circuit becomes one of the integral number of a frequency of the utilized AC power, and thus a continuity at the time of frequency variation is not satisfactory, an abnormal vibration arises on a load, or the load gets locked otherwise.

Meanwhile, in the case where the frequency conversion circuit is constituted of transistor elements, an arbitrary frequency can be generated, however, an ON/OFF control circuit and an independent power source for control will be necessary at every transistor elements, and thus the circuit inevitably becomes large in size and complicated at the same time, and the thyristor module and the diode module are connected by a lead wire or wiring pattern. Accordingly, a pulsating current of large power flows to the lead wire or wiring pattern, and a significant electromagnetic noise is radiated from the lead wire or wiring pattern, thus causing a noise on TV, audio equipment and others. Then, since the thyristor module and the diode module are separated from each other, the circuit inevitably becomes large in size, and a troublefree operation and a low cost requirement are not realized for the circuit.

An object of the present invention is to provide an electrical circuit device for supplying controlled frequency electric power to a load which permits miniaturization and enhancement of reliability.

Another object of an embodiment of the invention is to provide such a circuit device having a printed circuit base molded integrally with plastics material.

An object of an embodiment of the present invention is to provide a circuit module of simple configuration and capable of providing an arbitrary frequency, which permits a miniaturization and an enhancement of reliability using a circuit comprising thyristors, transistors and rectifier diodes.

According to the present invention there is provided a circuit module molded by electrically insulating material for supplying variably controlled frequency electric power to a load comprising:

a substrate plate of thermally conductive material having output terminals for supplying electric power to said load;

input terminals for receiving A.C. power for an A.C. power source;

signal terminals for receiving ON/OFF switching signals; and

electrical conductors connecting said output terminals, input terminals and signal terminals to form a circuit, wherein said circuit includes: a converting circuit means comprising a plurality of rectifying diodes electrically connected together for rectifying said A.C. power received via said input terminals, and a bridge circuit means, located adjacent to and coupled with said converting circuit means by electrical conductors, said bridge circuit means and said converting means being molded in said circuit module, and said bridge circuit means comprising a plurality of semiconductor switching elements connected in a bridge form for switching ON/OFF in response to said switching signals received via said signal terminals,

wherein, when switching signals are supplied to said signal terminals by a predetermined ON/OFF combination for obtaining electric power of desired frequency, a rectified output from said converting circuit means is transformed into electric power of said desired frequency and said electric power is supplied from said output terminals to said load.

According to a further aspect of the present invention there is provided a circuit module molded by electrically insulating material for supplying variably controlled frequency electric power to a load comprising:

a substrate plate of thermally conductive material for mounting a circuit thereon,

wherein said circuit comprises: a converting circuit means comprising a plurality of rectifying diodes electrically connected together for rectifying an A.C. power, and a bridge circuit means, located adjacent to and coupled with said converting circuit means by means of electrical conductors, said bridge circuit means and said converting circuit means being molded in said module, and said bridge circuit means comprising a plurality of arms, two of said arms having two transistors or a thyristor and transistor connected in series so that an electric current flows in a same direction,

wherein, when switching signals are supplied via signal terminals of said circuit module to said two transistors or thyristor and transistor by a predetermined ON/OFF combination for obtaining electric power of desired frequency, a rectified output from said converting circuit means is transformed into electric power

of said desired frequency and said electric power is supplied to said load.

Embodiments of the present invention provide an electric circuit capable of supplying a single-phase electric power and which permits a miniaturization and enhancement of reliability by thyristors, transistors and rectifier diodes.

An embodiment of the present invention provides a hybrid circuit device for supplying electric power to a load comprising printed circuit base means, molded integrally with plastic resin, for supplying electric power to the output terminals, a plurality of switching semiconductors forming a bridge circuit and adapted to provide ON/OFF switching operation to supply electric power of a desired frequency, and a plurality of rectifier diodes for rectifying the AC power and then feeding the rectified power to the switching semiconductors. The bridge circuit can have arms each of which has a thyristor and a transistor connected in series to the thyristor. Alternatively, the bridge circuit can be formed with arms each having two transistors that are connected together in series. In a further embodiment, a sensor is provided to sense temperature of the switching semiconductors.

In the molded structure described above, a radiation of electromagnetic noise will be prevented by shortening a lead wire or wiring pattern through which a large power flows, and the circuit can also be minaturized as a whole.

In the single-phase frequency conversion circuit

constructed as above, radiation of electromagnetic noise will be prevented by shortening a lead wire or wiring pattern through which a large power flows, and the circuit can also be miniaturized as a whole.

BRIEF DESCRIPTION OF THE DRAWINGS

Figure 1 is a frequency conversion circuit diagram for illustrating an embodiment of the present invention,

Figure 2 is a diagram illustrating the case when 60 Hz output is obtained through the circuit shown in Figure 1,

Figure 3 is a diagram illustrating a zero cross output,

Figure 4 is an enlarged diagram showing an output waveform in one cycle,

Figure 5 is a diagram showing ON/OFF state of a photocoupler at every mode operation,

Figures 6 and 7 are operational diagrams showing a main operation of the controlling part shown in Figure 11,

Figure 8 is a diagram showing constant data of the output frequency,

Figure 9 is a diagram illustrating the case when another frequency output is obtained,

Figure 10 is an electric circuit diagram representing the circuit shown in Figure 1 by means of the molded device shown in Figure 11 or 13,

Figure 11 is a hybrid circuit diagram of a molded device to a conversion circuit according to an embodiment of the present invention,

Figure 12 is a sectional view taken along XII-XII in Figure 11 showing the molded device, and

Figure 13 is a frequency conversion circuit diagram according to another embodiment of the present invention.

The present invention will be described with reference to the accompanying drawings representing preferred

embodiments thereof. The illustrated embodiments merely show preferred embodiments of the invention and directed to a single-phase conversion circuit for the purpose of clarification only, but the present invention is not limited to the description of the preferred embodiments.

Referring first to Figure 1 showing an electronic circuit of a main part of a single-phase conversion circuit, a thyristor 1 has a cathode terminal connected to a collector terminal of a transistor 2. An ignition circuit having a photocoupler 3 is provided on a gate terminal of the thyristor 1. The thyristor 1 and the photocoupler 3 are connected to self-bias resistors 4 and 5, respectively. A bias circuit having a driving transistor 6 and a photocoupler 7 is provided on a base terminal of the transistor 2. The transistors 2 and 6 are connected at their base terminals with base resistors 9 and 8, respectively. A thyristor 10, similar to the thyristor 1, has an ignition circuit having a photocoupler 11 on a gate terminal of the thyristor 10. The thyristor 10 and the photocoupler 11 are connected with self-bias resistors 13 and 12, respectively. A transistor 14, similar to the transistor 2, is connected at its base terminal with a bias circuit having a driving transistor 15 and a photocoupler 16. The transistors 14 and 15 are connected at their base terminals with base resistors 18 and 17, respectively. The thyristors 1, 10 and the transistors 2, 14 are maintained ON state when the photocoupler are ON state.

A single-phase load 19 or, for example, a single-phase electric motor and the like, having its one end connected to a connection point between the cathode terminal of the thyristor 1 and the collector terminal of the transistor 2, and the other end connected to a connection point between a cathode terminal of the thyristor 10 and a collector terminal of the transistor 14.

A constant voltage circuit 20 is provided to generate + Vcc voltage, which is supplied to the transistors 6, 15 and the photocouplers 7, 16. The constant voltage circuit 20 has a rectifying part, a smoothing part and a stabilizing part, not shown.

A rectifying circuit 21 has four rectifying diodes 202, 203, 204, 205 connected in the form of a full bridge. A pulsating voltage rectified by the rectifying circuit 21 is impressed between anode terminals of the thyristors 1, 10 and emitter terminals of the transistors 2, 14.

A two-way photocoupler 22 is connected between output terminals of a utilized AC power source 201. An output of the photocoupler 22 is as illustrated by the item "(b)" when the operating voltage of a light emitting diode(LED) 206, 207 used on a photo transistor is taken into consideration, whereas the item (a) represents an output waveform of the utilized AC source. An output for which the output waveform is inverted by an inverter 23, that is, waveform shown in the item "(c)", is fed to a controlling part 24 (i.e., microcomputer or the like). The output corresponds to a

zero cross output of the utilized AC power source.

The controlling part 24 controls a frequency of the power fed to the load 19 according to a frequency signal incoming from a terminal F, lighting up the photo thyristors 209, 210, photo transistors 211, 212, and photo thyristors 213, 214 of the photocouplers 3, 7, 11 and 16 through a buffer 25 to determine an output frequency. Reference numerals 217 - 220 are reverse-blocking diodes, and 221 and 222 show capacitors.

In Figure 2 of the drawing, (d) indicates a pulsating current output of the rectifying circuit 21, (e) indicates a zero cross output of the AC power source, (f) indicates ON outputs of the photocouplers (A)3, (B)7, (C)11, (D)16 for obtaining the 60 Hz output, and (g) indicates a voltage impressed on the load 19. An arrow in full line and that in dotted line in (g) indicate directions of the voltage impressed so as to carry an electric current in the directions indicated by an arrow in full line and that in dotted line of the load 19 shown in Figure 1, respectively. That is, an electric current flows in the directions indicated by arrows in Figure 2 when a voltage is impressed in the directions indicated by arrows in Figure 2. Accordingly, when obtaining the 60 Hz output, the direction in which an electric current is carried may be changed according to the zero cross output shown in (e). In this case, the voltage same as a rated voltage of the AC power source is impressed on the load.

In Figure 2, (h) and (i) indicate those for changing a mean voltage impressed at 60 Hz in output frequency, wherein impression of the voltage is interrupted at time ( $t_1$ ), Time after a zero crossing time ( $t_0$ ), and further impression of the voltage is recommenced  $T_0$  time thereafter at time ( $t_2$ ). For impressing such voltage waveform, an ON/OFF operation of the photocoupler (B) (transistor 2) will be controlled to the times  $t_0$ ,  $t_1$ ,  $t_2$ ,  $t_3$  with the photocoupler (C) (thyristor 11), for example, kept on. The period of time  $T_1 + T_2 + T_3$  covers a half cycle of 60 Hz, and  $T_1 = T_2$  in this case. Accordingly, the time between  $T_1$  and  $T_2$  may be set on characteristics such as efficiency, output and the like of the load 19.

Accordingly, the controlling part 24 comprises controlling ON states of the photocouplers (A)3, (B)7, (C)11, (D)16 so as to obtain output waveforms shown in Figure 2 (see also Fig. 1).

In the conversion circuit constructed as above, the full-wave rectifying circuit 21, the thyristors 1, 10 and the transistors 2, 14 are contained within device 27 (Fig. 11), and the length of the wiring pattern for connecting the rectifying circuit 21 and the thyristors 1, 10 or the transistors 2, 14 can be made shorter. Accordingly, an effective length that the wiring pattern functions as an antenna becomes short, thus decreasing a radiation of electromagnetic noise. Further, a use of the device may realize a compaction of the circuit and a miniaturization of

the conversion circuit.

In the above-described embodiment of the frequency conversion circuit, by molding the rectifier element and the plurality of switching element integrally, an effective length in which the wiring or wiring pattern for connecting the rectifier element and the switching elements functions as an antenna can be shortened, a radiation of electromagnetic noise due to a carried pulsating current will be suppressed, and thus an influence to be exerted on other electronic equipment can be suppressed. Further, by using such a device, the space utilized can be lessened, and the electric circuit can also be miniaturized as a consequence.

An example of the conversion in an embodiment of the invention will be described specifically. The following description is subject to the frequency of a utilized AC power source being set into five stages at 60 Hz, 40 Hz, 30 Hz, 24 Hz and 20 Hz.

Figures 6 and 7 are operational diagrams for obtaining the aforementioned outputs, namely operational diagrams of the controlling part 24 shown in Figure 1. Figure 8 represents data at every frequency, wherein a mean voltage impressed on the load is determined according to times  $T_0$ ,  $T_1$ , a reference character "m" represents a count number of zero cross output indicating an end of one period, and "n"

represents a count number of the mode in a half period. That is, the direction in which an electric current is carried to a load is transferred from the direction indicated by the arrow shown in full line to that of the arrow shown in dotted line when "n" reaches a predetermined count number, and the current carrying direction is transferred from the direction indicated by the arrow shown in dotted line to that of the arrow shown in full line when "m" reaches a predetermined count number. Thus, the end of one period is detected on the count number of zero cross output, therefore the frequency can be changed in accordance with the zero cross output at all times.

First, starting and constant setting are carried out at step  $S_1$  ( $F = 1$ ,  $M = 0$ ,  $N = 0$ ). A frequency signal applied to the terminal F is supplied at step  $S_2$ , and data ( $m$ ,  $n$ ,  $T_0$ ,  $T_1$ ) according to the frequency is read from the table of Figure 8. Next, a presence of the zero cross output is detected at step  $S_3$  so that a first mode output in the half cycle can be synchronized with the zero cross output at all times. When the zero cross output is present, "1" is added to M and N to shift the mode next, and a new half cycle starting is set at step  $S_4$ . Next, " $N \geq n$ " is decided at step  $S_5$ . That is, whether the output waveform is on the side of arrow in full line (positive output) or on the side of arrow in dotted line (negative output) is decided, and when " $N \geq n$ ", the flag is rewritten to  $F = 0$  (indicating negative output) at step  $S_6$ . Accordingly, I mode output (positive output) or III mode (negative output) is decided to a value

of the flag and then so generated. The output is kept for the time  $T_1$  thereafter at step  $S_7$ . Whenever the time is up, "1" is added as  $N = N + 1$  at step  $S_8$  to the next mode output. Whether the next mode is II mode (positive output) or IV mode (negative output) is determined at step  $S_9$  and so generated. The output is kept for the time  $T_0$  thereafter at step  $S_{10}$ . After the time is up, "1" is added as  $N = N + 1$  at step  $S_{11}$  to the next mode output. Whether or not " $N \geq n$ ", that is, whether or not the output is changed to a negative output is decided at step  $S_{12}$  in this case, and if " $N \geq n$ ", then " $F = 0$ ". Whether I mode output (positive output) or III mode (negative output) is decided thereafter at step  $S_{13}$  and so generated. Next, " $M \geq m$ ", that is, whether or not the output for one period ends at the last mode of half cycle is decided at step  $S_{14}$ , and when the output for one period is finished,  $F, M$  and  $N$  are determined as  $F = 1$ ,  $M = 0$ , and  $N = 0$  at step  $S_{15}$  to return to step  $S_2$ , and when not yet, the mode output decided at  $S_{13}$  is kept until the time is up on the zero cross output at  $S_3$ .

In the above-described embodiment, whether the output is positive or negative is decided at the first and last modes of half cycle, and whether or not the output for one period ends is decided at every last modes of the half cycle, however, the case where the output frequency is set to other frequency than the above-mentioned embodiment is not necessarily limited thereto.

Figure 9 is a diagram showing a state when 40 Hz output

is obtained, wherein the 40 Hz output frequency ( $60/1.5 = 40$  Hz) is obtainable from carrying the latter half pulsating current second from the left in the direction indicated by an arrow in dotted line, that is, making a half cycle of the output waveform 1.5 times. ON states of the photocouplers (A), (B), (C), (D) in this case may be controlled as shown by the item (j) in Figure 9. As in the case of item (i) in Figure 2, a non-current carrying time  $T_0$  will be provided and a mean voltage impressed on the load may be regulated to an efficiency of the load. Items (k), (l), (m), (n) in Figure 9 indicate output waveforms when outputs of 40Hz, 30 Hz, 24 Hz, 20Hz are obtained, respectively.

To obtain various frequency outputs shown in Figure 9, a combination of waveforms in one cycle of the utilized AC power source may be changed. Figure 4 is an enlarged view of the one cycle (see item (i) in Fig. 2), wherein if a current carrying time to the load is  $T_1$  and a non-current carrying time is  $T_0$  (the aforementioned time), then the one cycle can be divided into  $T_1 \rightarrow T_0 \rightarrow T_1 \rightarrow T_1 \rightarrow T_0 \rightarrow T_1$ , and a combination of ON states of the photocoupler at each time can be classified into I mode  $\rightarrow$  II mode  $\rightarrow$  III mode  $\rightarrow$  IV mode  $\rightarrow$  III mode (for each mode status refer to Fig. 5). The illustration is that for obtaining 60 Hz output, however, when compared with other frequency outputs shown in Figure 9, the time is repeated all the time as  $T_1 \rightarrow T_0 \rightarrow T_1$  notwithstanding that the output frequency varies. Accordingly, different frequency outputs will be obtainable

by changing an output order of I mode to IV mode. For example, when obtaining 40 Hz output, the mode comes in I → II → I → I → II → III → III → IV → III (for one period), while the time is as  $T_1 \rightarrow T_0 \rightarrow T_1 \rightarrow T_1 \rightarrow T_0 \rightarrow T_1 \rightarrow T_1 \rightarrow T_0 \rightarrow T_1$  (for one period).

In this embodiment, since arms with a cathode terminal of the thyristor connected to a collector terminal of the transistor are connected in parallel into two circuits, and a single-phase load is connected between nodes of the cathode terminal and the collector terminal of each arm, a carried current controlled by the thyristor is chopped by the transistor and an output of the half cycle can be divided at every plural time. Accordingly, an operation similar to the case where the circuit is configured entirely by transistors is obtainable even from using thyristors, and thus the cost can be reduced significantly by using the thyristors and an independent power source for ignition circuit becomes unnecessary as compared with the transistors, thus simplifying the circuit.

Figure 10 shows an electronic circuit which has some change in layout from that of Figure 1. In Figure 10, the thyristors 1, 10, the transistors 2, 14, the full-wave rectifying circuit 21 and a temperature sensor 28 which are shown in Figure 11 are molded and separated within a single module 27. A temperature protecting part 26 outputs a signal to the controlling part 24 to a current carrying to the load when the temperature detected by the temperature

sensor 28 connected through terminals 3, 3' reaches a predetermined temperature.

Figure 11 is an internal circuit diagram of the molded device 27 connected to terminals 1 to 12 shown in Figure 10. The thyristors 1 and 10 can be replaced by transistors 109, 110 as illustrated in Figure 13. In Figures 11 and 13, reference numerals 101-104 represent rectifying diodes and 105-108 represent reverse-blocking diodes.

Figure 12 is a longitudinal sectional view of the molded device 27 shown in Figure 11. In Figure 12, the device 27 has an insulation layer 30 on an aluminium substrate 29, a wiring pattern 31 on the insulation layer 30, a chip 32 of the transistor, a lead wire 33 extending outwardly for connection with external electrical elements an outer frame 34 of a suitable synthetic resin, a terminal 301 and a filler 35 of a suitable synthetic resin, filled in a space between the outer frame 34 and the aluminium substrate 29.

While the invention has been described in the specification and illustrated in the drawings with reference to preferred embodiments, it will be understood by those skilled in the art that various changes may be made and equivalents may be substituted for elements thereof in accordance with applications and technical field to be applied without departing from the scope of the invention. In addition, many modifications may be made to adapt a

particular situation or material to the teachings of the invention without departing from the essential scope thereof.

The present Application was divided from U.K. Patent Application No. 8826674 (publication No. 2212677A) which relates to an electric circuit for supplying controlled frequency electrical power to a load.



CLAIMS

1. A circuit module molded by electrically insulating material for supplying variably controlled frequency electric power to a load comprising:

a substrate plate of thermally conductive material having output terminals for supplying electric power to said load;

input terminals for receiving A.C. power for an A.C. power source;

signal terminals for receiving ON/OFF switching signals; and

electrical conductors connecting said output terminals, input terminals and signal terminals to form a circuit, wherein said circuit includes: a converting circuit means comprising a plurality of rectifying diodes electrically connected together for rectifying said A.C. power received via said input terminals, and a bridge circuit means, located adjacent to and coupled with said converting circuit means by electrical conductors, said bridge circuit means and said converting means being molded in said circuit module, and said bridge circuit means comprising a plurality of semiconductor switching elements connected in a bridge form for switching ON/OFF in response to said switching signals received via said signal terminals,

wherein, when switching signals are supplied to said signal terminals by a predetermined ON/OFF combination for obtaining electric power of desired frequency, a rectified output from said converting circuit means is



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transformed into electric power of said desired frequency and said electric power is supplied from said output terminals to said load.

2. A circuit module according to claim 1, further comprising temperature sensing means adjacent to said circuit, said temperature sensing means being molded with the electrically insulating material together with said bridge circuit.

3. A circuit module according to claim 1 or 2 wherein said semiconductor switching elements are transistors.

4. A circuit module molded by electrically insulating material for supplying variably controlled frequency electric power to a load comprising:

a substrate plate of thermally conductive material for mounting a circuit thereon,

wherein said circuit comprises: a converting circuit means comprising a plurality of rectifying diodes electrically connected together for rectifying an A.C. power, and a bridge circuit means, located adjacent to and coupled with said converting circuit means by means of electrical conductors, said bridge circuit means and said converting circuit means being molded in said module, and said bridge circuit means comprising a plurality of arms, two of said arms having two transistors or a thyristor and transistor connected in series so that an electric current



flows in a same direction,

wherein, when switching signals are supplied via signal terminals of said circuit module to said two transistors or thyristor and transistor by a predetermined ON/OFF combination for obtaining electric power of desired frequency, a rectified output from said converting circuit means is transformed into electric power of said desired frequency and said electric power is supplied to said load.

5. A circuit module molded by electrically insulating material for supplying variably controlled frequency electric power to a load substantially as herein described with reference to Figures 11 and 12 or Figure 13 with reference to Figure 1 or Figure 1 and any of Figures 2 to 10 of the accompanying drawings.

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